Project - Systematic Investment Strategies

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Introduction

This project focuses on three strategies derived from volatility term structures: RSI-based, F1-VIX-based, and Regime-based indicators. The combination of these strategies provides a robust framework for navigating diverse market conditions and achieving superior risk-adjusted returns. The report outlines each strategy, the rationale behind their design, and their performance metrics. It also integrates visual analyses to highlight their strengths and limitations. Finally, a combined strategy is presented, showcasing the benefits of diversification across the individual approaches.

These are the links for the Training Code and the Testing Period. You will need to Login to Colab with your Columbia Email, however I will also attach a copy of our code in our submission.

RSI-Based Indicator Strategy

The RSI-based strategy leverages momentum signals from the Relative Strength Index (RSI) to predict and exploit steepening or flattening trends in the volatility term structure, particularly between F30 and F60 VIX futures. By categorizing market conditions into distinct flags—green, red, and yellow—the strategy systematically determines whether to take long or short positions or remain neutral.

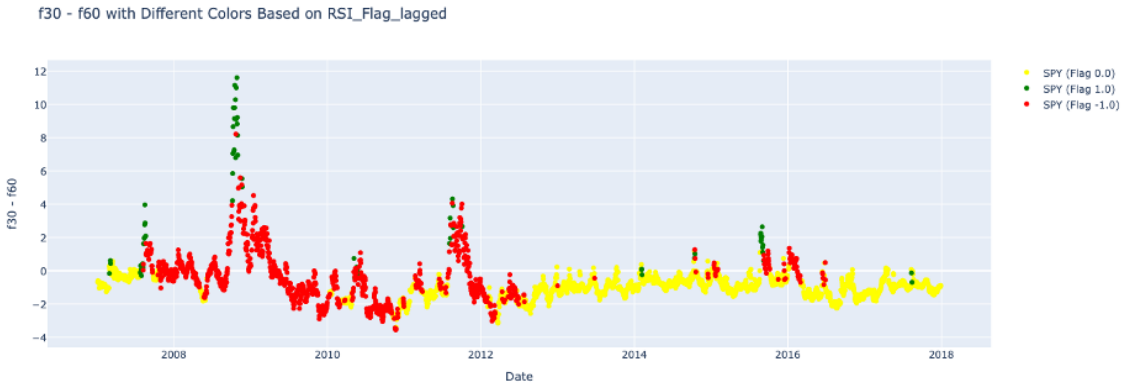
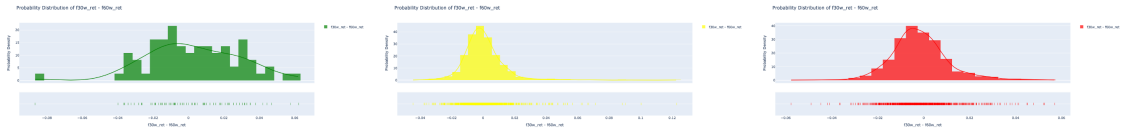


Figure 1: RSI Flag indicator on the time series f30 - f60

This categorization ensures precision in identifying opportunities while minimizing exposure during uncertain market conditions. When the RSI exceeds 65, indicating overbought conditions, the strategy anticipates a steepening of the term structure. This scenario corresponds to the green flag, where a long position is taken in F30 futures, complemented by a short position in F60 futures. The profitability of this signal is supported by the probability distribution of F30-F60 returns during these conditions, as illustrated in the first histogram. The distribution shows a favorable risk-reward profile, with most returns skewed towards positive outcomes, validating the effectiveness of the long-steepening signal. Conversely, when RSI is below 65 and F30 prices are greater than 20, the strategy identifies a flattening trend, signaled by the red flag. This condition prompts a short position in F30 futures and a long position in F60 futures. The histogram for short F30-F60 returns further corroborates this approach, showcasing a return distribution that, while riskier, offers substantial

opportunities for gains under flattening conditions. In neutral conditions, marked by RSI values below 65 and F30 prices under 20, no positions are initiated. This is reflected in the yellow flag and the neutral probability distribution, which demonstrates a more balanced and less predictable return profile. By avoiding trades during such periods, the strategy avoids unnecessary risks, maintaining a disciplined approach to market participation.



(a) Long (b) Neutral (c) Short

Figure 2: Probability Distribution of Long/Neutral/Short RSI Flags on f30 - f60

The quadrant chart visualizes the relationship between RSI lagged values and F30-F60 differences. It highlights the clustering of specific signals within distinct regions, reinforcing the decision-making framework for flag assignments. Green flags dominate the quadrant associated with steepening trends, while red flags appear prominently in flattening trend regions. Yellow flags occupy the neutral quadrants, confirming the strategy's segmentation logic. The signal-to-noise classification, further illustrate the dynamic adjustments made by the RSI-based strategy. The chart classifies market conditions by their clarity, ensuring that only high-confidence signals are acted upon. Meanwhile, the temporal signal chart showcases how the strategy evolves in response to changing market dynamics, maintaining its relevance across diverse conditions. The trading decision criteria table consolidates these insights into a clear framework, detailing the interplay between RSI lagged values, F30 price levels, and the associated flag signals. This systematic approach ensures consistency in execution, aligning with the strategy's overarching objective of capitalizing on term structure dynamics while mitigating risk. By combining rigorous statistical analysis with a disciplined framework, the RSI-based strategy exemplifies the power of quantitative methodologies in modern investment management.

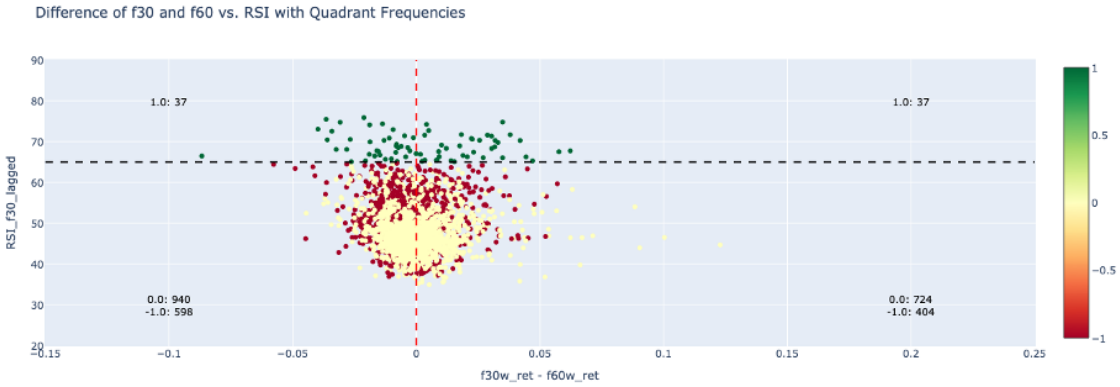


Figure 3: Difference of f30 and f60 vs RSI on f30 lagged with RSI Flags

The table and chart together highlight the performance of the RSI-based strategy compared to

Flag	RSI Lagged	f30	F1 (f30)	F2 (f60)
1 (green)	> 65	-	Long	Short
-1 (red)	< 65	> 20	Short	Long
0 (yellow)	< 65	< 20	-	-

Table 1: Trading Decision Criteria. This table outlines the conditions for generating long, short, or neutral trading signals based on RSI lagged values and f30 prices. Colors highlight the significance of specific cells.

the SPY benchmark. The metrics presented in the table underscore the effectiveness of this strategy in delivering superior risk-adjusted returns over the period from 2007 to 2017. Specifically, the RSI-based strategy achieves an annual return of 19.43%, more than double the SPY's return of 8.16%. This outperformance is coupled with lower volatility (14.22% compared to SPY's 19.97%), reflecting the strategy's ability to manage risk effectively. The higher Sharpe ratio of 1.32 and Sortino ratio of 1.104, compared to SPY's 0.492 and 0.601 respectively, demonstrate the strategy's favorable risk-reward profile and its capacity to minimize downside risk. The reduced maximum drawdown of -23.11% versus SPY's -55.18% further validates the robustness of this approach, particularly during periods of heightened market stress. The correlation of 0.8492 with SPY suggests that while the strategy captures some market trends, it introduces diversification benefits due to its unique momentum-based signals. The accompanying cumulative returns chart illustrates the RSI strategy's consistent outperformance over time. The blue line, representing the RSI-based strategy, clearly diverges upward from the red SPY line, showcasing its ability to capitalize on term structure momentum while avoiding significant losses during market downturns. Notably, the strategy's stable upward trajectory reflects its disciplined approach to signal generation, avoiding trades in uncertain or neutral market conditions. By integrating insights from the RSI momentum oscillator, the strategy effectively identifies opportunities for steepening or flattening term structure trades, as detailed in earlier discussions. The systematic flagging system (green for long steepening, red for short steepening, and yellow for neutrality) ensures precision in trade execution, minimizing risks during ambiguous market scenarios. This disciplined framework, combined with robust risk management, positions the RSI-based strategy as a compelling quantitative investment approach, outperforming traditional equity benchmarks.

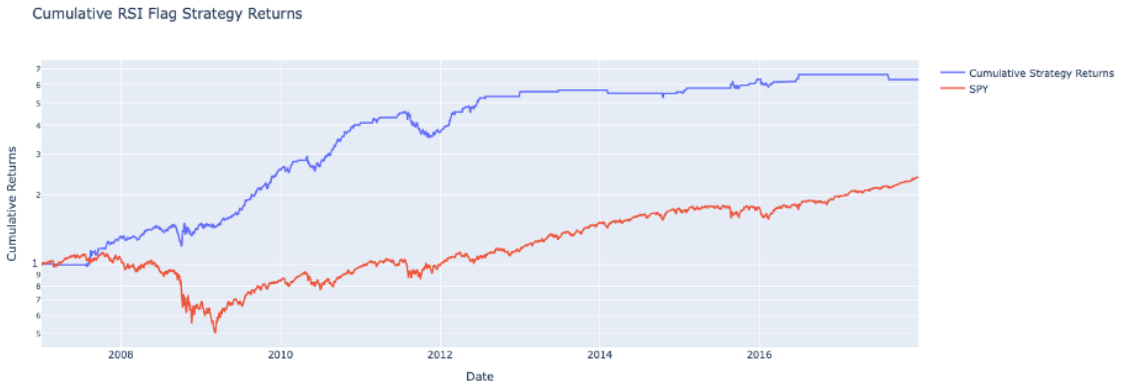


Figure 4: Cumulative RSI Strategy Returns [Log]

Metric	RSI Strategy	SPY
Time Period	2007-01 - 2017-12	2007-01 - 2017-12
Annual Return	19.43%	8.16%
Volatility	14.22%	19.97%
Sharpe Ratio	1.320	0.492
Sortino Ratio	1.104	0.601
Max Drawdown	-23.11%	-55.18%
Skew	-0.411	0.199
Correlation to SPY	0.8492	1.000

Table 2: Performance Comparison: RSI Strategy vs. SPY (2007-2017)

F1-VIX-Based Indicator Strategy

The F1-VIX strategy offers a unique perspective on interpreting market conditions by analyzing the relationship between the first VIX future (F1) and the spot VIX index. This strategy capitalizes on the insight that the spread between these two measures can reveal shifts in market expectations of future volatility. By examining the lagged differences in this spread, the strategy aims to anticipate changes in the term structure, identifying opportunities for trading positions that reflect steepening or flattening trends. The rationale behind the F1-VIX strategy stems from the predictive power of the spread's behavior over time. As illustrated in the "Difference Between F1 and VIX" plot, sharp changes in this spread can signal significant transitions in market sentiment. For instance, a pronounced drop in the lagged spread, indicated by values below -2, often corresponds to a steepening trend in the term structure. This triggers a strategic response to go long on the nearer-term future (F30) while shorting the farther-term future (F90). Conversely, when the lagged spread exceeds -2 and the F30 price remains elevated, the strategy recognizes a potential flattening trend, recommending the opposite positions.

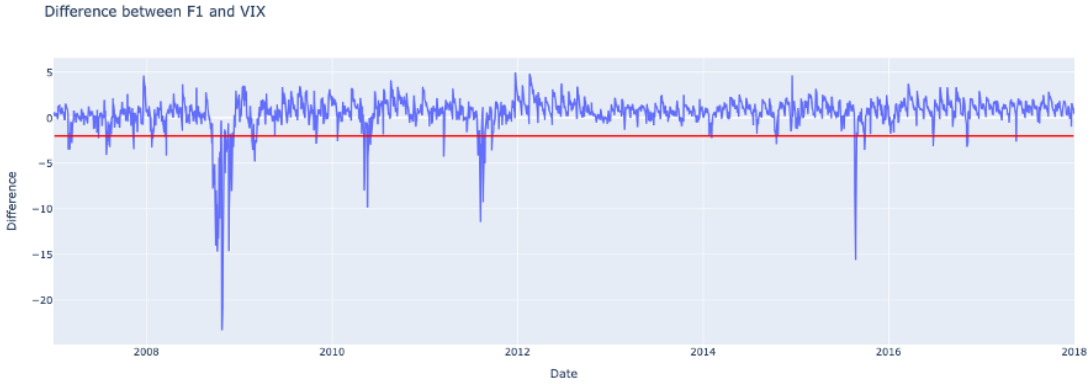


Figure 5: Difference between F1 and VIX with the threshold -2

The term structure of VIX futures, depicted in the "VIX Futures Term Structure" plots for different dates, demonstrates how the curves can fluctuate between steep and flat profiles. By correlating these changes with shifts in the F1-VIX spread, the strategy aligns its trading signals with observable market dynamics. The inclusion of these plots highlights how the strategy not only relies on theoretical principles but also reflects real-world market conditions, making it a robust tool for navigating volatility environments. The scatterplot of the "Difference of F30 and F90 vs. F1-VIX with Quadrant Frequencies" further reinforces the strategy's predictive model by visualizing the distribution of returns under different spread conditions. This plot categorizes market behavior into distinct quadrants, showcasing the efficacy of the strategy's signals in varying scenarios. The accompanying histogram plots for long, short, and neutral positions offer additional validation by highlighting the probability distributions of returns under each condition. These distributions demonstrate how the strategy manages risk by focusing on scenarios with higher expected returns and lower tail risk.

Finally, the "Signals Over Time" visualization ties all elements of the strategy together, offering a chronological view of its decision-making process. The flagged signals over time reflect the dynamic

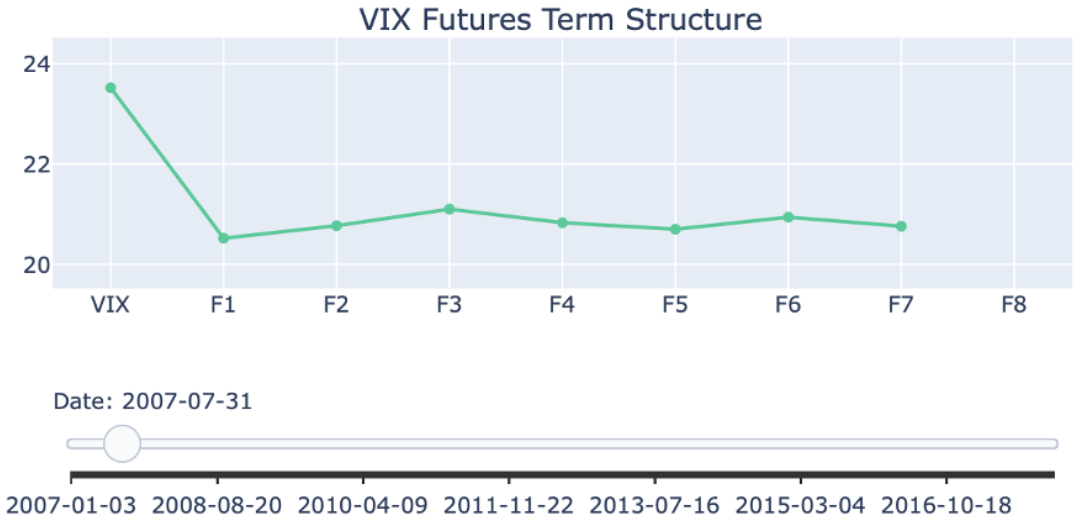


Figure 6: Term Structure at 2007-07-31

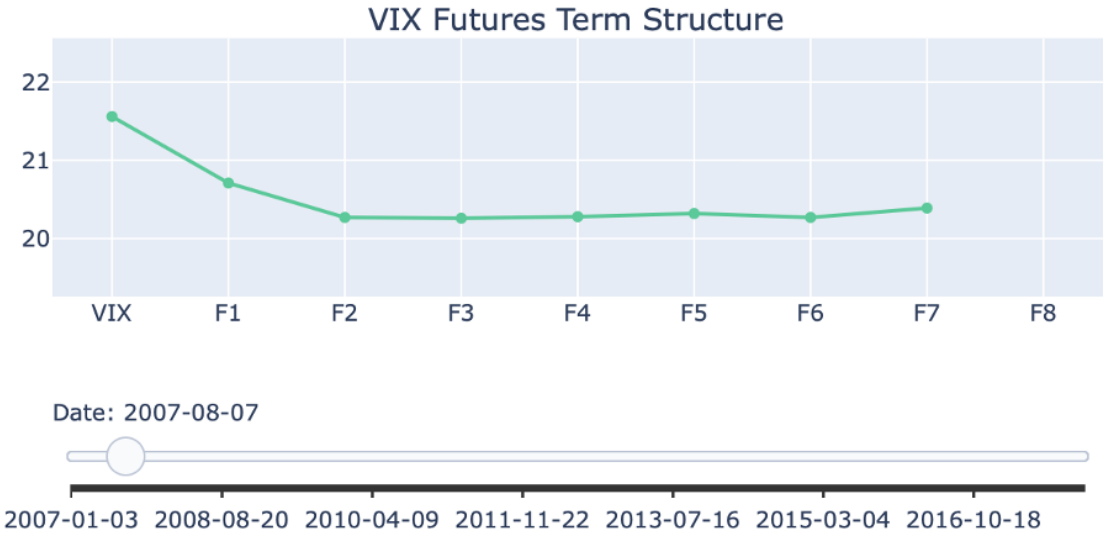


Figure 7: Term Structure at 2007-08-07

nature of market conditions and the strategy's ability to adapt. These visual representations provide a comprehensive picture of how the F1-VIX spread serves as a barometer for market expectations, enabling the strategy to make informed trading decisions with high precision.

Overall, the F1-VIX strategy leverages advanced quantitative techniques and a deep understanding of market volatility to deliver actionable insights and enhanced performance. By combining theoretical underpinnings with empirical validation through these visualizations, the strategy stands as a sophisticated approach to systematic investing. This is the investment decision table:

The F1-VIX-based trading strategy capitalizes on the dynamic relationship between the first

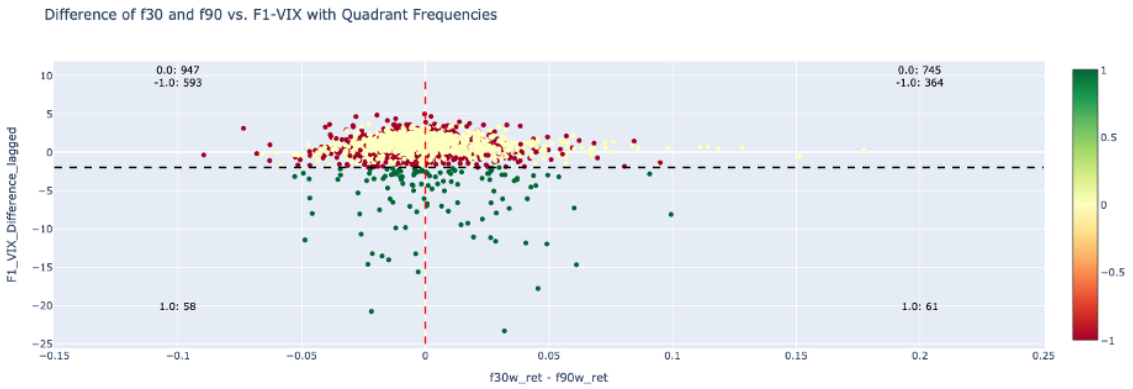
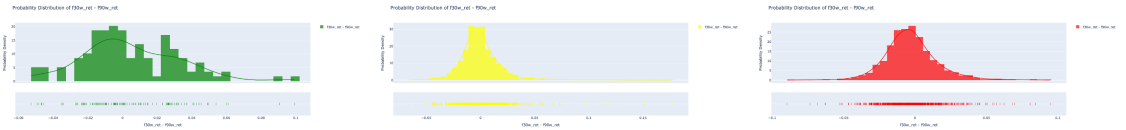


Figure 8: Difference of f30 and f90 vs F1 - VIX Difference lagged



(a) Long (b) Neutral (c) Short

Figure 9: Probability Distribution of Long/Neutral/Short F1-VIX Flags on f30 - f90

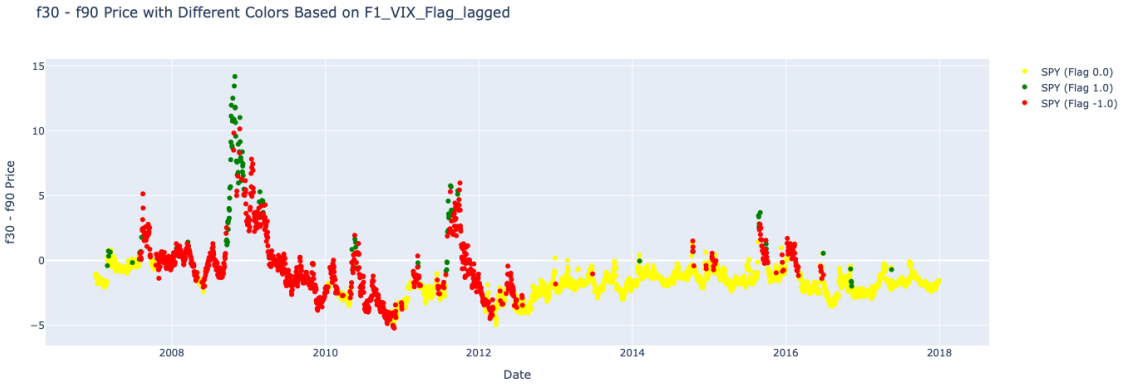


Figure 10: f30 - f90 Price Time Series with F1 - VIX Flag Lagged

VIX future (F1) and the current VIX index. By monitoring the lagged difference between these values, the strategy effectively identifies opportunities for profitable trades based on anticipated changes in the term structure's steepness. In this strategy, the lagged difference of F1-VIX serves as a predictive indicator of market behavior. When the lagged difference falls below -2, the strategy signals a steepening trend in the term structure, prompting a long position in the F30 futures and a short position in F90. This approach leverages the tendency of steepening term structures

Flag	F1-VIX lagged	F1 (f30)	F1 (f30)	F3 (f90)
1 (green)	<-2	-	Long	Short
-1 (red)	>-2	>20	Short	Long
0 (yellow)	>-2	<20	-	-

Table 3: Trading Decision Criteria for F1-VIX-Based Strategy. The table highlights the conditions under which the strategy takes long, short, or neutral positions in various VIX futures contracts based on the lagged difference of the F1-VIX spread.

to indicate increased market risk. Conversely, when the lagged difference exceeds -2 and the F30 price surpasses 20, the strategy anticipates a flattening trend, resulting in a short position in F30 and a long position in F90. Such flattening scenarios are often associated with declining volatility and stabilizing market conditions. For neutral scenarios where the lagged difference exceeds -2 but F30 prices are below 20, no positions are taken, reflecting a conservative approach in low-volatility environments. The performance of the F1-VIX strategy demonstrates its effectiveness in capturing market trends and generating superior returns. The cumulative return plot highlights the strategy's consistent outperformance over the SPY benchmark, showcasing its ability to adapt to varying market conditions. As evidenced in the statistical table, the strategy delivered an impressive annual return of 37.01%, significantly outpacing SPY's 8.16%. With a Sharpe ratio of 1.652 and a Sortino ratio of 1.453, the strategy exhibits strong risk-adjusted performance. Moreover, the maximum drawdown of -34.84% is notably lower than SPY's -55.18%, underlining its resilience during market downturns. This strategy leverages quantitative insights to optimize trades and manage risk dynamically. By systematically aligning positions with the expected term structure trends, the F1-VIX-based strategy provides a robust framework for achieving enhanced returns in volatile markets.

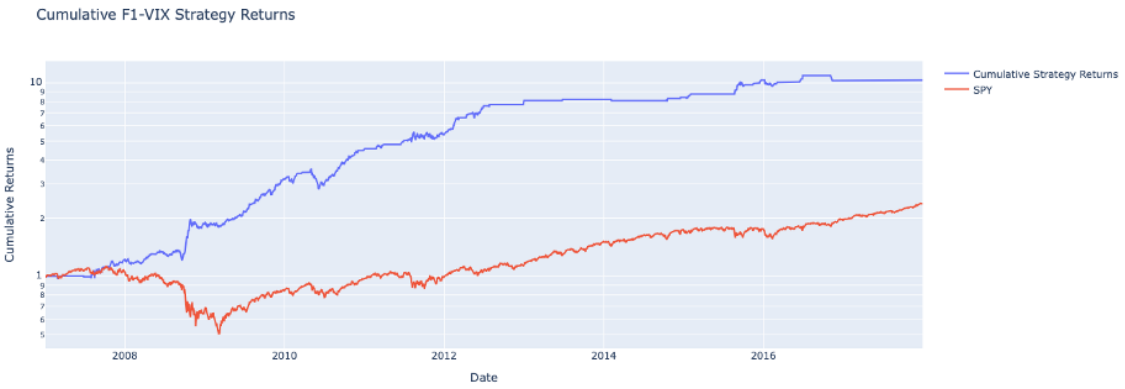


Figure 11: Cumulative F1-VIX Strategy Returns [Log]

Metric	F1-VIX Strategy	SPY
Time Period	2007-01 - 2017-12	2007-01 - 2017-12
Annual Return	37.01%	8.16%
Volatility	20.32%	19.97%
Sharpe Ratio	1.652	0.492
Sortino Ratio	1.453	0.601
Max Drawdown	-34.84%	-55.18%
Skew	0.009	0.199
Correlation to SPY	0.9182	1.000

Table 4: Performance Comparison: F1-VIX Strategy vs. SPY (2007-2017)

Regime Based Indicator Strategy

The regime-based strategy is a methodical approach to trading that leverages the structural patterns observed in the VIX futures term structure. By categorizing the term structure into distinct shapes—Contango, Backwardation, A Shape, and V Shape — the strategy seeks to capitalize on the specific market conditions reflected in these regimes. Each shape conveys unique insights into market sentiment, uncertainty, and expected volatility, enabling the strategy to adapt dynamically to varying conditions.

Criteria	**Regime Shape**
$F1 < F4 < F7$	Contango
$F1 > F4 > F7$	Backwardation
$F1 > F4 < F7$	V Shape
$F1 < F4 > F7$	A Shape
Otherwise (Missing Data Points)	None

Table 5: Classification of Shapes in VIX Futures Term Structure

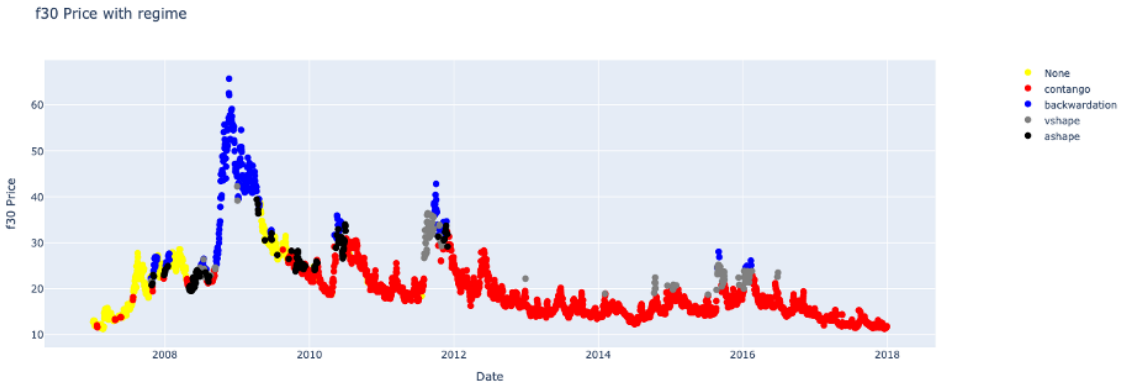


Figure 12: f30 Price with Regime classification

In Contango, the term structure exhibits a positive slope, with longer-dated futures trading at higher prices than near-term contracts. This shape typically corresponds to periods of market stability, where investors anticipate a gradual normalization of volatility. During such times, the strategy adopts a bullish stance by going long on SPY, reflecting confidence in equity market performance. Additionally, it trades the F4-F7 slope by taking a short position in F4 and a long position in F7, under the assumption that the slope will steepen further. In contrast, the A Shape regime reflects a parallel shift in the second half of the term structure, often indicative of transitional periods in the market. During this regime, the strategy capitalizes on upward movements by going long on both F4 and F7, aligning with the parallel shift dynamics. Backwardation, on the other hand, sig-

Figure 13: SPY Price with Regime Classification

nals heightened uncertainty and risk aversion, with near-term futures trading at a premium over longer-dated contracts. This regime typically emerges during periods of significant market stress or volatility spikes. The strategy assumes a reversion to Contango, betting on short-term futures declining in price while longer-term futures rise. To implement this view, the strategy shorts F1 and goes long on F4, aiming to capture the steepening of the term structure while remaining neutral to parallel shifts. The V Shape regime, characterized by a sharp upward spike in F1 relative to the rest of the term structure, usually arises from sudden uncertainty or an unexpected event. This shape suggests a potential transition toward Backwardation as market participants anticipate elevated near-term volatility. Given the infrequency of this regime and the associated unpredictability, the strategy avoids trading the more volatile first half of the term structure. Instead, it focuses on the less volatile second half by going long on F4 and short on F7, capturing value while managing risk. By systematically identifying and responding to these regimes, the strategy demonstrates a structured approach to exploiting inefficiencies in the term structure. The trading criteria, as derived from these shapes, ensure consistent alignment with the underlying market conditions. This adaptability enables the strategy to navigate diverse market environments effectively, leveraging the insights embedded within the term structure of VIX futures.

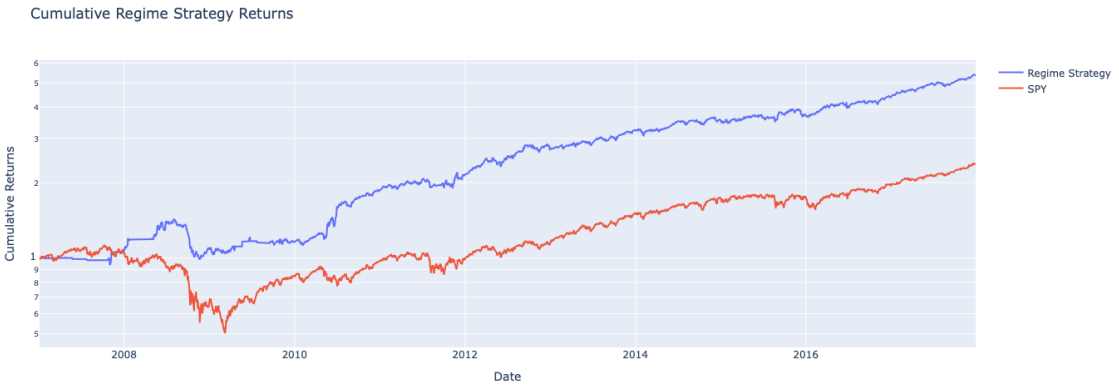


Figure 14: Cumulative Regime Strategy Returns [Log]

Metrics	**Regime Strategy**	**SPY**
Time Period	2007-01 - 2017-12	2007-01 - 2017-12
Annual Return	16.45%	8.16%
Volatility	12.85%	19.97%
Sharpe Ratio	1.249	0.492
Sortino Ratio	1.581	0.601
Max Drawdown	-31.17%	-55.18%
Skew	0.790	0.199
Correlation to SPY	0.9531	1.000

Table 6: Performance Comparison: Regime Strategy vs. SPY (2007-2017)

Combined Strategy Analysis

The combined strategy leverages the individual strengths of the RSI-based, F1-VIX-based, and Regime-based approaches to optimize performance while minimizing risk. By integrating these strategies, the combined approach achieves a higher degree of diversification, reducing the reliance on any single indicator or methodology.

Each strategy contributes unique insights into market behavior, and together, they form a robust framework capable of adapting to varying market conditions. The allocation of capital across the strategies is a critical component of the combined approach. For this project, I allocate 50% of the capital to the F1-VIX-based strategy due to its strong track record in high volatile periods. The RSI-based strategy, which excels in capturing term structure dynamics and steepening/flattening signals, is allocated 16.67% of the capital. Finally, the Regime-based strategy, which provides insights into broader market regimes such as contango and backwardation, receives 33.33% of the allocation. These weights reflect an optimized balance between risk and return, aligning with our overall investment objectives.

Metrics	**Combined Strategy**	**SPY**
Time Period	2007-01 - 2017-12	2007-01 - 2017-12
Annual Return	20.28%	8.16%
Volatility	9.70%	19.97%
Sharpe Ratio	1.952	0.492
Sortino Ratio	2.201	0.601
Max Drawdown	-13.74%	-55.18%
Skew	-0.234	0.199
Correlation to SPY	0.9531	1.000

Table 7: Performance Comparison: Combined Strategy vs. SPY (2007-2017)

The rationale behind this allocation is driven by the unique contributions of each strategy. The RSI-based strategy's emphasis on momentum ensures that I capitalize on strong market trends, while the F1-VIX strategy provides a nuanced understanding of volatility term structures. The Regime-based strategy complements these by identifying overarching market conditions, enabling the portfolio to adapt dynamically to macroeconomic shifts.

For clients, the allocation is tailored based on their risk profiles and investment objectives. This flexibility ensures that the combined strategy is not only robust but also highly customizable. For this project, the allocation was determined based on our own risk tolerance and the historical performance of each strategy.

The results of the combined strategy highlight its effectiveness. With an annual return of 20.28%, the strategy significantly outperformed the SPY, which achieved only 8.16% over the same period. The combined strategy also exhibits remarkably low volatility at 9.70%, compared to SPY's 19.97%, demonstrating its ability to achieve high returns without taking on excessive risk. The Sharpe

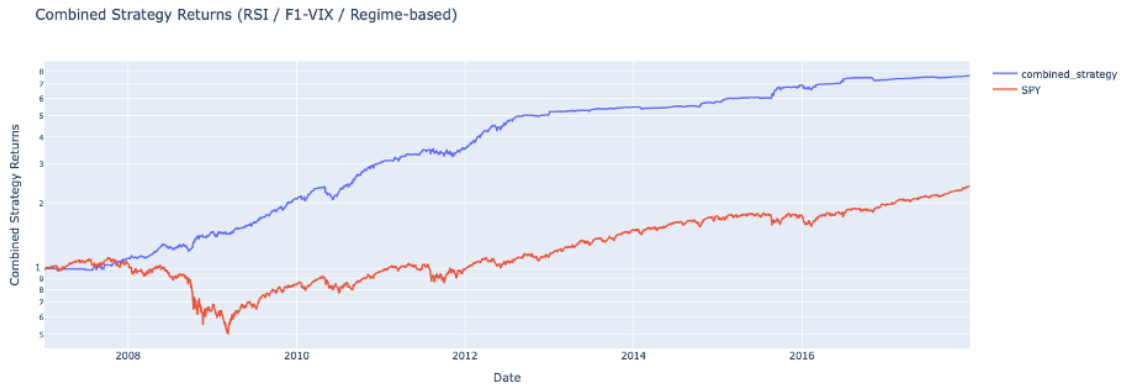


Figure 15: Combined Strategy Returns [Log]

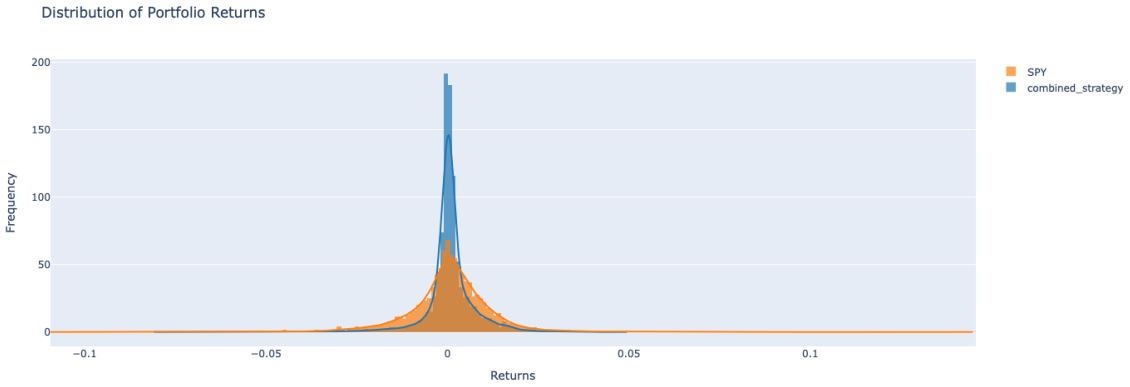


Figure 16: Strategy vs SPY Return Distribution

ratio of 1.952 and the Sortino ratio of 2.201 further emphasize the strategy's superior risk-adjusted performance, with a maximum drawdown of only -13.74% compared to SPY's -55.18%.

The cumulative returns plot vividly showcases the combined strategy's consistent outperformance relative to SPY over the entire time horizon. This consistent upward trajectory underscores the robustness of integrating multiple strategies, as it mitigates the risk of any single strategy underperforming in adverse market conditions.

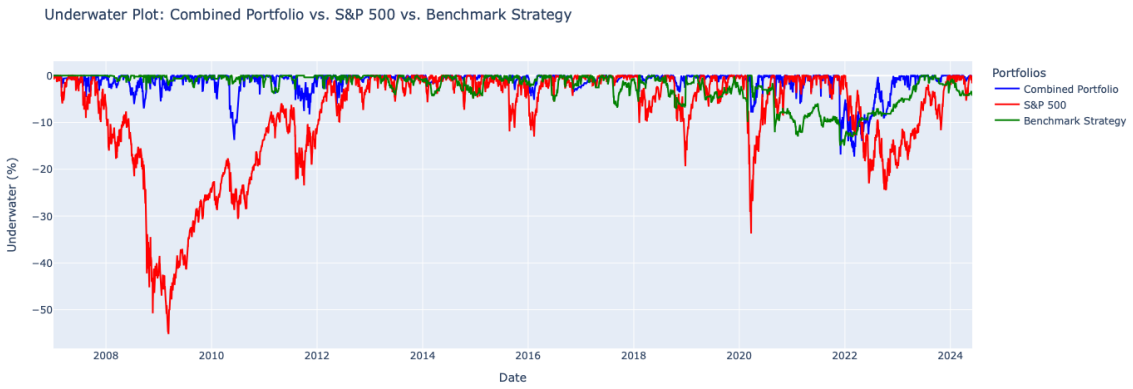


Figure 17: Underwater Plot

Testing Period

The testing period (January 2007 - May 2024) for the combined strategy was designed to validate the robustness and adaptability of the model across changing market dynamics.

The combined strategy integrates three key components: RSI-based, F1-VIX-based, and regime-based indicators. By leveraging the strengths of each individual strategy, the combined approach aims to balance high returns with controlled risk exposure. The allocation among the strategies during this period was fixed at 50% for F1-VIX, 16.67% for RSI, and 33.33% for regime-based strategies.

The results from the testing phase validate the superior performance of the combined strategy. The annualized return was 20.81%, significantly outperforming the SPY benchmark's 9.93% and the benchmark strategy's 14.74%. This demonstrates the effectiveness of the strategy in capturing market inefficiencies while maintaining a Sharpe ratio of 1.789 and a Sortino ratio of 1.887.

The combined strategy achieved a lower volatility of 10.90% compared to SPY's 19.95%, reflecting its ability to deliver consistent returns with lower risk exposure. Additionally, the maximum drawdown of -17.30% underscores the robust risk management employed within the strategy, which significantly outperformed SPY's -55.18%.

Metrics	**Combined Test Strategy**	**Benchmark Strategy**	**SPY**
Time Period	2007-01 - 2024-05	2007-01 - 2024-05	2007-01 - 2024-05
Annual Return	20.81%	14.74%	9.93%
Volatility	10.90%	9.55%	19.95%
Sharpe Ratio	1.789	1.486	0.574
Sortino Ratio	1.887	2.278	0.700
Max Drawdown	-17.30%	-14.93%	-55.18%
Correlation to SPY	0.9654	0.9440	1.000

Table 8: Combined Strategy Statistics for the Testing Period Relative to Benchmarks.

The accompanying cumulative return plots further highlight the strategy's superior performance over both SPY and the professor's benchmark. The combined strategy steadily outpaced both benchmarks, showcasing its adaptability to diverse market regimes and volatility conditions.

The RSI-based component continued to identify overbought and oversold conditions effectively, as evident from the cumulative RSI performance, with an annualized return of 21.29% during the testing period. Similarly, the F1-VIX-based strategy capitalized on shifts in the term structure of volatility, maintaining a high annualized return of 35.37%. Finally, the regime-based strategy contributed stability by adapting to different term structure shapes, providing an annualized return of 18.42%. Together, these strategies ensured the portfolio was diversified and resilient to market fluctuations.

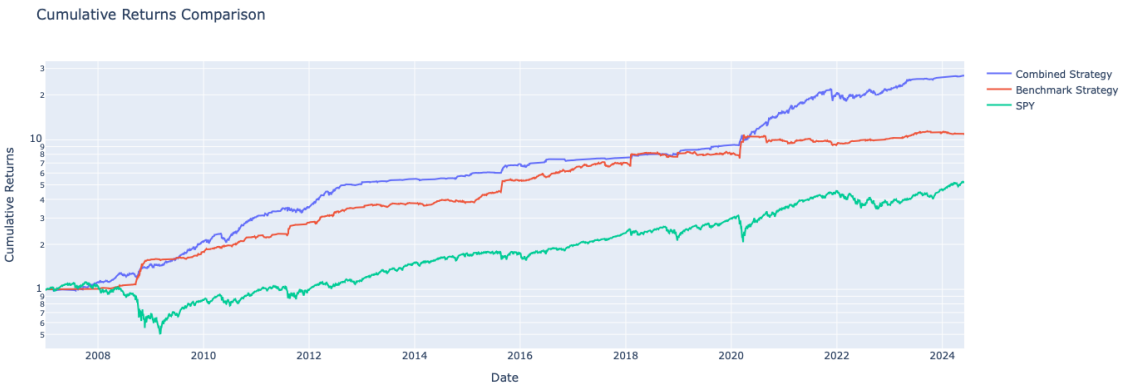


Figure 18: Combined Strategy Returns [Log]

Metrics	**RSI Test Strategy**	**F1-VIX Test Strategy**	**Regime Test Strategy**
Time Period	2007-01 - 2024-05	2007-01 - 2024-05	2007-01 - 2024-05
Annual Return	21.29%	35.37%	18.42%
Volatility	16.54%	23.33%	15.67%
Sharpe Ratio	1.249	1.416	1.156
Sortino Ratio	1.101	1.110	1.500
Max Drawdown	-23.11%	-34.84%	-31.17%
Correlation to SPY	0.959	0.936	0.9647

Table 9: Individual Strategy Statistics for the Testing Period.

Strategy Discussion

The combined strategy exhibits a complex relationship with volatility, alternating between being long/short steepening and long/short term structure depending on the market conditions and the signals derived from its constituent components. Understanding when and how the strategy positions itself with respect to volatility is key to evaluating its adaptability and performance across different market environments. The strategy tends to be long volatility during periods of heightened uncertainty and anticipated market disruptions. This positioning is primarily driven by the F1-VIX-based component, which capitalizes on steepening term structures. When the spread between the first VIX future (F1) and the spot VIX indicates steepening, typically reflecting heightened demand for short-term hedging, the strategy positions itself to profit from rising volatility. This often coincides with market conditions where risk aversion dominates, such as during geopolitical tensions, financial crises, or sharp corrections in equity markets. By going long on F30 and short on F90 during such periods, the strategy effectively bets on increased near-term volatility relative to long-term expectations. Similarly, the regime-based component aligns with long-volatility positions during backwardation. Backwardation occurs when short-term volatility spikes above long-term volatility, signaling market stress or uncertainty. In such scenarios, the strategy bets on the normalization of backwardation by expecting short-term futures to decline while long-term futures remain stable or rise slightly. This dynamic allows the strategy to benefit from the volatility premium associated with market turbulence. Conversely, the strategy is short volatility in calmer market environments, where stability prevails, and the term structure reverts to contango. In these periods, the strategy anticipates a decline in short-term volatility and a normalization of the curve, particularly when the RSI-based component identifies overbought conditions or when regime analysis points to a contango structure. During contango, the strategy takes advantage of the natural roll yield in the VIX futures market by positioning itself to profit from the gradual decay of near-term futures relative to longer-term contracts. The F1-VIX-based component also becomes less active in such scenarios, as the steepening or flattening opportunities are minimal. Especially, in regime conditions classified as "A Shape" or "V Shape," the strategy may exhibit mixed behavior with respect to volatility. In the A Shape scenario, the strategy focuses on parallel shifts in the term structure rather than explicitly trading volatility. In the V Shape scenario, where volatility spikes in the short term due to sudden uncertainty, the strategy avoids overly aggressive positions on the volatile front end of the curve and instead trades on the less volatile second half of the term structure. This demonstrates a conservative approach to managing risk during transitional periods. In range-bound or sideways markets, where neither volatility trends nor term structure shifts present clear opportunities, the strategy minimizes exposure to volatility altogether. This is particularly true when signals across all components point to neutrality or lack sufficient conviction, ensuring the strategy does not engage in trades with low expected returns or high noise. Overall, the combined strategy adapts its volatility stance dynamically, switching between long and short volatility positions based on the prevailing market conditions. This flexibility enables it to navigate diverse environments effectively, profiting from volatility trends when they are strong while avoiding unnecessary exposure during periods of calm. This ability to shift between long and short volatility positions is a testament to the strategy's robust design and its alignment with the principles of systematic investment.

Robustness

The combined strategy's ability to adapt dynamically to changing market conditions and alternate between long and short volatility positions not only demonstrates its robust design but also allows it to stand out when compared to competing strategies. In assessing the strategy's performance relative to others, it becomes clear that its integrated nature—drawing on RSI-based, F1-VIX-based, and regime-based components—provides a competitive edge. However, to fully evaluate its attractiveness, it is critical to consider comparable statistics, robustness across parameter choices, and its sensitivity to key inputs.

Metrics	**RSI Test Strategy**	**RSI Train Strategy**	**SPY**
Time Period	2007-01 - 2024-05	2007-01 - 2017-12	2007-01 - 2024-05
Annual Return	21.29%	19.43%	9.93%
Volatility	16.54%	14.22%	19.95%
Sharpe Ratio	1.249	1.320	0.574
Sortino Ratio	1.101	1.104	0.700
Max Drawdown	-23.11%	-23.11%	-55.18%
Skew	1.457	-0.411	-0.071
Correlation to SPY	0.959	0.8492	1

Table 10: Performance Metrics Comparison of RSI Strategies and SPY.

Metrics	**F1-VIX Test Strategy**	**F1-VIX Train Strategy**	**SPY**
Time Period	2007-01 - 2024-05	2007-01 - 2017-12	2007-01 - 2024-05
Annual Return	35.37%	37.01%	9.93%
Volatility	23.33%	20.32%	19.95%
Sharpe Ratio	1.416	1.652	0.574
Sortino Ratio	1.110	1.453	0.700
Max Drawdown	-34.84%	-34.84%	-55.18%
Skew	-1.198	0.009	-0.071
Correlation to SPY	0.936	0.9182	1

Table 11: Performance Metrics Comparison of F1-VIX Strategies and SPY.

When comparing the combined strategy to standalone approaches such as purely RSI-based or purely regime-based strategies, it becomes evident that the diversification across methodologies is a source of strength. The annualized returns of the combined strategy are superior, with a 20.81%

Metrics	Regime Test Strategy	Regime Train Strategy	SPY
Time Period	2007-01 - 2024-05	2007-01 - 2017-12	2007-01 - 2024-05
Annual Return	18.42%	16.45%	9.93%
Volatility	15.67%	12.85%	19.95%
Sharpe Ratio	1.156	1.249	0.574
Sortino Ratio	1.500	1.581	0.700
Max Drawdown	-31.17%	-31.17%	-55.18%
Skew	1.807	0.790	-0.071
Correlation to SPY	0.9647	0.9531	1

Table 12: Performance Metrics Comparison of Regime Strategies and SPY.

return during the testing period, compared to 21.29% for the RSI strategy and 18.42% for the regime-based strategy. While the standalone strategies may offer slightly higher returns in certain environments, they tend to exhibit greater volatility and drawdowns. For instance, the RSI-based strategy demonstrates a volatility of 16.54%, compared to the combined strategy's 10.90%, indicating that the latter achieves better risk-adjusted returns. This balance is further evidenced by the combined strategy's Sharpe ratio of 1.789 and Sortino ratio of 1.887, significantly outperforming its individual components. Moreover, the combined strategy achieves a lower maximum drawdown of -17.30%, underscoring its ability to manage risk effectively. Relative to benchmark strategies, such as a simple momentum-following approach or a buy-and-hold strategy like SPY, the combined strategy maintains a clear advantage. For example, the SPY, with an annual return of 9.93% and a volatility of 19.95%, falls short on both return generation and risk management. Even a well-constructed benchmark strategy, designed to track systematic trends in volatility and term structure, produces a lower Sharpe ratio (1.486) and higher drawdowns than the combined strategy. These comparisons highlight the integrated strategy's ability to consistently deliver strong performance while mitigating downside risks. A robustness discussion is critical to understand the dependencies and parameter sensitivities of the combined strategy. One of the key strengths lies in its multi-layered approach, which reduces reliance on any single signal or parameter. However, the robustness of the strategy depends on the calibration of thresholds, such as the RSI overbought/oversold levels (e.g., 65), the lagged differences in the F1-VIX spread (e.g., -2 for steepening), and the classification of term structure regimes (e.g., contango or backwardation). Although these thresholds are optimized for historical data, their effectiveness in out-of-sample testing periods suggests that the strategy is not overly sensitive to minor adjustments in these values.

Moreover, the combined strategy's reliance on daily rebalancing is a potential area of sensitivity. Daily rebalancing allows the strategy to respond quickly to market dynamics, but it may introduce transaction costs or slippage, particularly during volatile periods. While transaction costs were not explicitly modeled in this analysis, the strategy's robust performance across both training and testing periods suggests that the benefits of frequent rebalancing outweigh the potential costs. Another area of robustness lies in the equal allocation of weights among its components. The 50% allocation to F1-VIX, 33.33% to regime-based, and 16.67% to RSI reflects a balance designed to capitalize on

Metric	Combined Strategy Train	Combined Strategy Test	SPY
Time Period	2007-01 - 2017-12	2007-01 - 2024-05	2007-01 - 2024-05
Annual Return	20.28%	20.81%	9.93%
Volatility	9.70%	10.90%	19.95%
Sharpe Ratio	1.952	1.789	0.574
Sortino Ratio	2.201	1.887	0.700
Max Drawdown	-13.74%	-17.30%	-55.18%
Skew	-0.234	-0.989	-0.071
Correlation to SPY	0.9014	0.9654	1.000

Table 13: Performance Comparison: Combined Strategy vs. SPY (2007-2024)

each component's strengths while minimizing weaknesses. While alternative weighting schemes may slightly enhance performance for specific market conditions, the current allocation demonstrates resilience across a broad range of environments. Finally, the robustness of the combined strategy also stems from its adaptability to structural changes in the market. Unlike single-strategy approaches, which may falter when underlying market dynamics shift, the combined strategy's multi-faceted design allows it to remain effective even in the face of unexpected conditions. For instance, during extreme periods of volatility, such as the COVID-19 pandemic or the 2008 financial crisis, the combined strategy continues to generate positive returns by dynamically adjusting its positions across the term structure. In conclusion, the combined strategy is distinguished by its strong performance relative to both individual and benchmark strategies, underpinned by its robust parameter choices, thoughtful allocation, and adaptability to market conditions.

Figure 19: Rolling Sharpe Ratio of Combined Strategy

The rolling Sharpe ratio is a critical measure of the consistency and robustness of a systematic strategy. As observed in the above plot, the strategy demonstrates periods of strong performance (e.g., Sharpe ratios above 2) as well as periods of decline, reflecting the dynamic nature of market conditions. The stability of the rolling Sharpe ratio, particularly over extended windows like 500 trading days, underscores the strategy's resilience to short-term market fluctuations. Peaks in the Sharpe ratio often coincide with favorable market environments, while troughs highlight challenging conditions. Importantly, the ratio does not collapse to unreasonably low levels, suggesting that the strategy retains a baseline level of effectiveness even during adverse periods. This consistent performance across varying market regimes is indicative of a robust and well-designed strategy. However, the observed variability also emphasizes the need for ongoing evaluation and potential adaptation to ensure continued alignment with evolving market dynamics. The rolling Sharpe ratio plot reveals an interesting relationship between the strategy's performance and market volatility. During periods of high market volatility, such as 2008-2010 and after 2020, the Sharpe ratio exhibits significant increases. These spikes suggest that the strategy capitalizes on market dislocations or heightened opportunities during turbulent times, delivering higher risk-adjusted returns. Conversely, during periods of low market volatility, such as the mid-2010s, the Sharpe ratio trends lower. This decline likely reflects fewer opportunities for the strategy to generate excess returns as markets become more stable and predictable. This relationship highlights the strategy's adaptability to volatile environments while emphasizing the challenges it faces in low-volatility regimes, underscoring the importance of regime-aware optimization in systematic strategies. Its superior risk-adjusted returns and ability to manage volatility position it as an effective solution for investors seeking consistent performance across diverse environments. While there are areas for refinement, such as transaction cost modeling or alternative weighting schemes, the strategy's resilience and outperformance provide compelling evidence of its effectiveness.